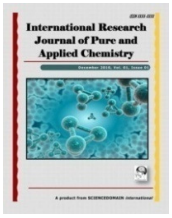

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Delayed Shifts in pH Responses to Weak Acids in Spring Water Exposed to Circular Rotating Magnetic Fields: A Narrow Band Intensity-Dependence

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Authors' contributions

This work was completed in collaboration between all authors who contributed equally to the design, execution, and analyses of the experiment as well as the writing of the manuscript.

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ABSTRACT

The time required for the shift in pH after addition of small quantities of a weak acid into fixed volumes of spring water was measured once per minute while the sample was exposed to magnetic field configurations that have been shown to influence photon emissions and to produce non-local effects in other experiments. The rotating magnetic fields were generated through a circular array of eight solenoids first with an accelerating angular group and decelerating phase velocity followed by a decelerating angular group and accelerating phase velocity for a total of 18 min. There was an intensity dependent increase in the latency (from 185 s to 886 s) required for the pH to decrease (towards acidity) between ~0.13 and ~0.33 μT (microTesla) where an asymptote was evident. The duration was systematically related to the magnetic energy within the

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volumes of spring water associated with various intensities. Quantitative analyses indicated that the most likely mechanism involved the energy per molecule associated with the numbers of HCO_3^- and H^+ ions in the fixed volumes. These results suggest that weak magnetic fields with specific rotational configurations within physiologically relevant volumes of water containing several ion species can delay the onset of acid-base responses in buffered systems.

Keywords: pH; weak magnetic fields; changing angular velocity; response latency; 10^{-20} J.

1. INTRODUCTION

The effects of weak physiologically-patterned magnetic fields upon aqueous systems such as those containing concentrations of ions similar to those found in cells have implications for theoretical and applied chemistry. Toledo et al. [1] measured the enthalpies, viscosity and surface tension of water exposed to 45 to 65 mT static magnetic fields. Their data indicated the exposure disrupted intra-cluster hydrogen bonds. Gang et al. [2] found that stronger (0.16 T) static magnetic fields affected the diffusivity of solutes. We reasoned that appropriately-patterned and much weaker magnetic fields at specific intensities could facilitate cohesion between intermolecular networks of hydrogen bonds that would be reflected in increased response latencies to shifts in pH following addition of small quantities of proton donors to liquid water.

Persinger [3] has suggested that the mobile protons associated with H_3O^+ ions could mediate many of the subtle changes in the properties of water following exposures to magnetic flux. The product of the average viscosity of water and the ratio of the magnetic moment of a proton and unit charge produces a force that when applied across the distance of two hydrogen bonds is ~$1.7 \cdot 10^{-20}$ J. This is remarkably similar to the energy associated with second shell hydrogen bonds and is consistent with proton mobility [4].

That strong static magnetic fields affect aqueous systems has been shown by multiple experiments. Oshitani et al. [5], who reviewed this area of research, showed that "residual" changes in different physical properties of water, a type of "memory effect," were frequent but inconsistent phenomena. Measurements by atomic force microscopes indicated that the effects of uniform magnetic fields applied to aqueous samples slowly became evident and approached an asymptote after 10 t0 20 min. Oshitani et al. [5] found that the thickness of the layer of water molecules and ions absorbed on a surface (as well as the surface potential of an electrolyte solution) responded differentially to either pulsed, alternating or static magnetic fields.

With a flux density of 0.4 T which is within the range known to produce a maximum magnetic effect on selected aqueous properties, they found that the time required for the maximum effects upon layer thickness by the pulsed, alternating and static fields were 6, 10, and 20 min respectively. The latency of the appearance of the effect decreased with increasing frequency up to 90 Hz which was the limit of their equipment. The residual effect upon layer thickness after 30 min exposure was at least 5 days for the pulsed and alternating fields and about 3 days for the static field. The static field effect was no longer measureable after 5 days.

Gang et al. [2] measured diffusion velocity of a solute (ink) in different aliquots of spring water after 1 hr exposures to a 0.16 T static (horseshoe) magnetic field every 15 min for several hours. They found sudden and protracted increases in diffusion velocity that were a function of the volume of the initially exposed water. The sudden increases for the successive 80 µL aliquots from the original 25 cc, 50 cc, and 100 cc volumes were 5.9 hr, 7.4 hr, and 8.6 hr, respectively. The effect was not measured in similar volumes of water exposed to a 7 Hz, 140 to 400 nT field generated by a Helmholtz coil. Gang et al. [2] suggested that the energy stored within the water as a function of volume was maintained with increased viscosity at the boundary of interfacial and bulk water as described by Del Giudice and Preparata [6]. The dissipation of this "intrinsic organization" induced by the magnetic field within the water was presumed to be mediated by hydronium ions.

Murugan and her colleagues, as reported by Persinger [3], found that exposure of spring water in the dark to a physiologically patterned, weak (0.3 to 0.6 µT) magnetic field that had also been shown to slow the growth of different types of cancer cells in culture but not normal cells [7], resulted in an increase and shift in the peak of photon counts as measured by fluorescence spectrophotometer. The shift within the 1 cc

samples was about 10 nm (to a longer wavelength) within the range of 350 to 466 nm. It involved an increase of about 100 photon counts over the reference value and was equivalent to a net energy change of about 10^{-20} J.

We [8] have observed that the nature of the temporal-spatial application of the magnetic field is a major factor that determines the range of the intensity that most effectively influences the target material which was aqueous mixtures. One particular pattern involves rotating magnetic fields produced by the serial activation of a ring of solenoids. If the phase velocity of the pattern that is being constantly applied is opposite to the changing angular velocity of the rotating field (group velocity) conspicuous changes in the duration of a constant pH value (despite addition of protons) occur as a function of the intensity of the magnetic field. Here we show the threshold for this effect involves intensities within the microTesla range.

2. MATERIALS AND METHODS

There were a total of 61 experiments completed over separate days (not more than one per day) over several weeks. For each experiment a 125 cc beaker containing 25 cc of spring water (4 mM of $HCO3^-$; 1.77 mM Ca^{++}; 76 µM of Cl^-; 1.3 mM of Mg^{++}, 41.9 µM of $NO3^-$, 61 µM of $SO4^{--}$, 17.9 µM of K^+ and 43.5 µM of Na^+) was placed in the center of a circular array of pairs of solenoids as described by Dotta and Persinger [9]. The equipment is also described in U.S. Patent 6,312,376: b1; November 6, 2001 and Canadian Patent No. 2214296.

Each pair of solenoids was composed of reed relays (Radio Shack, 275-0232). They exhibited a coil resistance of 250 ohms and a potential of 5 V DC (nominal current, 20 mA). Each pair was arranged in plastic film canisters and connected such they were pairs of north and south poles. The circumference of the equally spaced solenoids that were separated by 45 degrees from each other was about 60 cm Fig. 1.

The magnetic fields were generated from custom-constructed equipment such that columns of numbers each between 0 and 255 were converted to between -5 and +5 V (127=0 V) by a digital-to-analogue converter (DAC). The first field exhibited a decelerating phase (frequency) modulation while the second field exhibited an accelerating phase (frequency) modulation. Figures of their shapes in real time have been published elsewhere [10]. The spectral analyses of the two patterns are shown here in Figs. 2 and 3. Although the significance of their spectral structure must still be established, they are presented here for reference. We have found that spectral densities of complex wave forms can be more informative for revealing physical chemical and biological processes than the observable or first order temporal patterns.

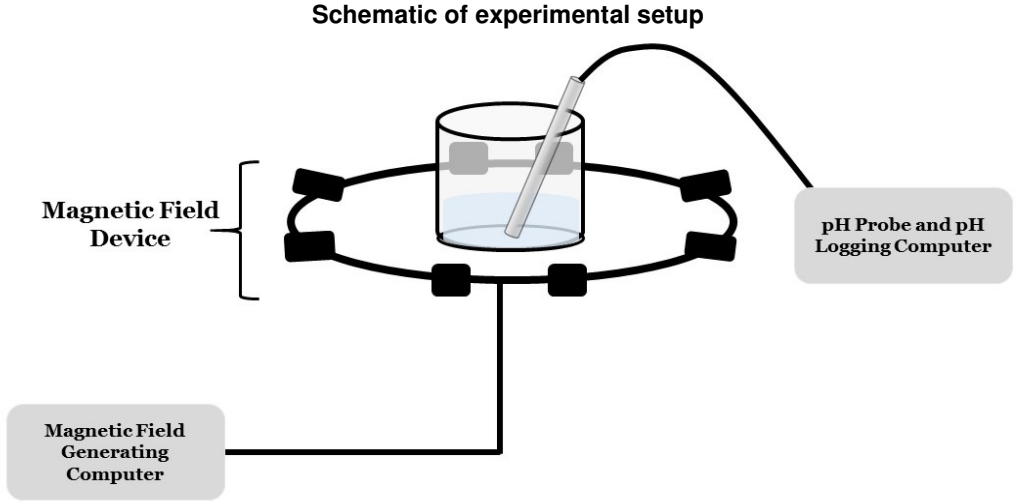
Schematic of experimental setup
Magnetic Field Device
pH Probe and pH Logging Computer
Magnetic Field Generating Computer

Fig. 1. Schematic of apparatus for generating changing angular accelerating magnetic fields around a volume of spring water within which pH was measured over time. The rates of change and patterns of the magnetic fields delivered through 8 solenoids were controlled by computer software and custom-constructed digital-to-analogue converters

The protocol was identical to the procedure by which excess correlation has been demonstrated over a distance of 10 m for both photon emissions and shifts in pH in non-local settings [11]. During those experiments we observed a conspicuous maintenance of level of the baseline pH after several injections of proton donors when the changing angular velocity magnetic field was operating. Without the magnetic field the decrease in pH in this preparation occurred very quickly. Consequently we examined this "holding" effect across a variety of additional intensity levels.

The first field (decelerating phase) was generated around the circular array of solenoids with an accelerating velocity. This was completed by adding 2 ms to the duration the field was presented to each solenoid beginning with 20 ms ("20+2"). Consequently the time required to complete one rotation was 104 ms or 9.6 Hz. The second field (accelerating phase velocity) was presented with decelerating group velocity. This was completed by subtracting 2 ms from the duration of the field presentation at each solenoid ("20-2"). Consequently the time required for one completion was 216 ms or 4.6 Hz.

The first field configuration was presented for 6 minutes. After 4 min of exposure 50 µL of 0.83 M acetic acid was injected into the 25 cc of spring water with a microLiter syringe. The initial pH of the spring water was 7.4±0.1. Immediately after the second field was activated (for an additional 12 min), 50 µL quantities of acetic acid were injected every min (min 8, 9, 10, 11, 12, 13, 14, 15, 16). Hence there were a total of 10 injections. The pH values were recorded once per second by Dr. Daq systems (Pico Technology, United Kingdom) and were sensitive to 0.01 pH unit.

Over the 61 experiments different intensities of magnetic fields were applied. They were controlled by the software from the computer by which the fields were generated. In addition to the no field condition there were 10 different intensity settings. There were between 3 and 9 experiments per intensity condition. Direct measurement in the middle of the ring of solenoids with a power meter allowed average measurements of the strength in mG which ranged from 0.35 to 5.5 mG.

The time elapsed ("holding time") after the first injection before the shift in pH occurred from the injections of the acetic acid as well as the shift in pH between the end and beginning of the experiment were obtained from the data files and loaded into SPSS-16. Analyses of variance as a function of intensity were completed. *Post hoc* analyses (Tukey's $p<.05$) were completed to discern group differences; polynomial analyses revealed the linearity of the relationship.

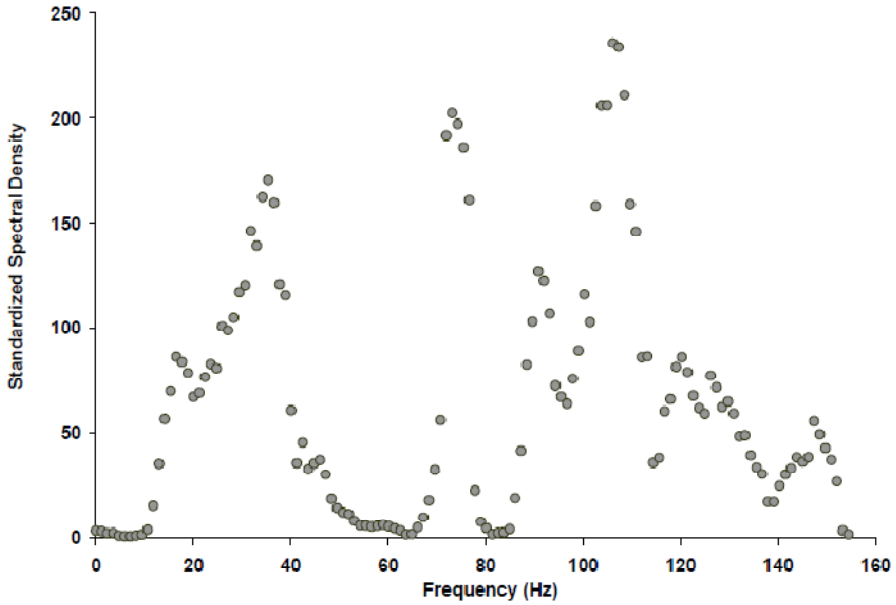

Fig. 2. Standardized spectral density of the decelerating phase modulated pattern generated with an accelerating angular velocity of the rotating magnetic field within which the water samples were placed

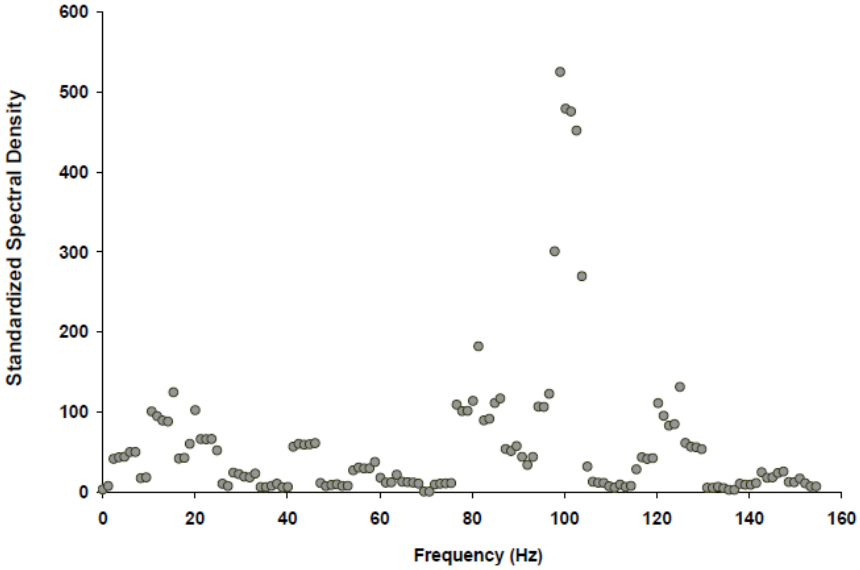

Fig. 3. Standardized spectral density of the accelerating phase modulated pattern generated within a decelerating angular velocity of the rotating magnetic fields within which the water samples were placed

3. RESULTS

Fig. 4 shows the average "holding" duration in seconds after the repeated injections of the same small quantities of acetic acid before the decrease in pH began to occur as a function of the intensity of the field. Oneway analyses of variance as a function of intensity indicated a significant difference [F (11, 49) =24.95, p<.001] for holding durations between the intensities. Exposures to the different intensities explained about 85% of the variance (effect size) in the holding durations. *Post hoc* analyses indicated the major source of the difference was between the holding durations below 1.3 mG and 3.3 mG. The holding durations associated with each of the field strengths ≤1.6 mG did not differ significantly from each other. The holding durations for intensities ≥3.3 mG did not different significantly from each other. Polynomial analyses indicated that the first order best fit equation was linear and there was no significant deviation from this term.

Fig. 5 shows the average net change in pH for each of the intensity conditions. The maximum decrease in pH was about 3.0, that is a change from 7.4 to 4.4 for the control (no field conditions). There was no significant shift in pH within the more intense magnetic field conditions until the "holding" duration was exceeded. When that occurred, the pH in all conditions decreased to 4.4 which was the same value displayed by the control (no field) conditions.

The 11 points shown in Fig. 5 were analyzed separately from the total data base. Correlation (Pearson) analyses indicated a strong relationship between the intensity of the applied magnetic field and the "holding" duration (r=0.96) and the total net shift in pH (r=-0.98). The inverse correlation coefficient between holding duration and net shift in pH was -0.91. Partial correlation analyses holding each of the variables constant did not appreciably diminish the correlation between field strength and holding duration (partial r=0.77, p<.001) or between field strength and net shift in pH (partial r=-0.88, p<.001). Direct analyses of the total data (excluding the no-field controls) set revealed similar effects. The correlation between field strength and holding time decreased from 0.88 to 0.72 after covarying for the change (decrease) in pH and the correlation between field strength and change in pH decreased from -0.86 to -0.62 after covarying for holding duration.

Fig. 6 shows the inverse release between the holding duration and the net shift in pH as a function of magnetic field intensities. The data were standardized (z-scored) in order to allow direct comparison. The interface for the inflection of both curves occurred around 2 mG or $2 \cdot 10^{-7}$ T.

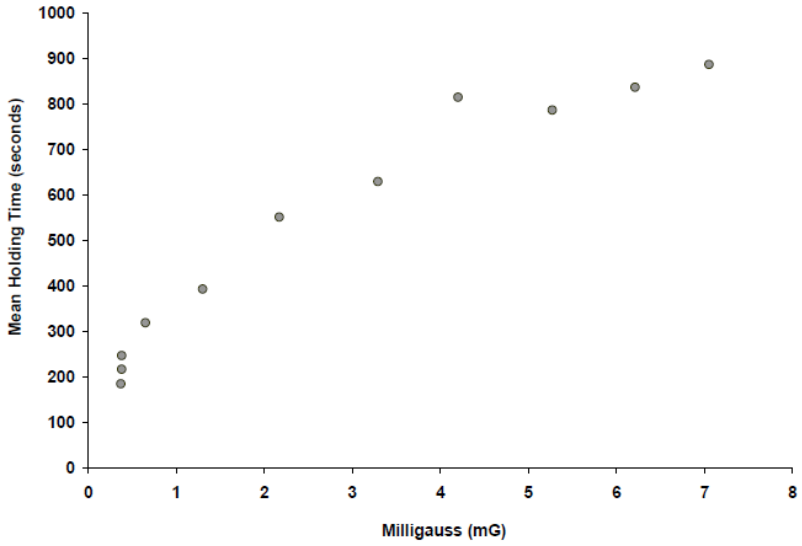

Fig. 4. Mean holding duration (in seconds), or the latency before the sudden decrease in pH in response to additions of a weak acid to the spring water as a function of the intensity of the rotating magnetic accelerating-decelerating angular velocity magnetic field

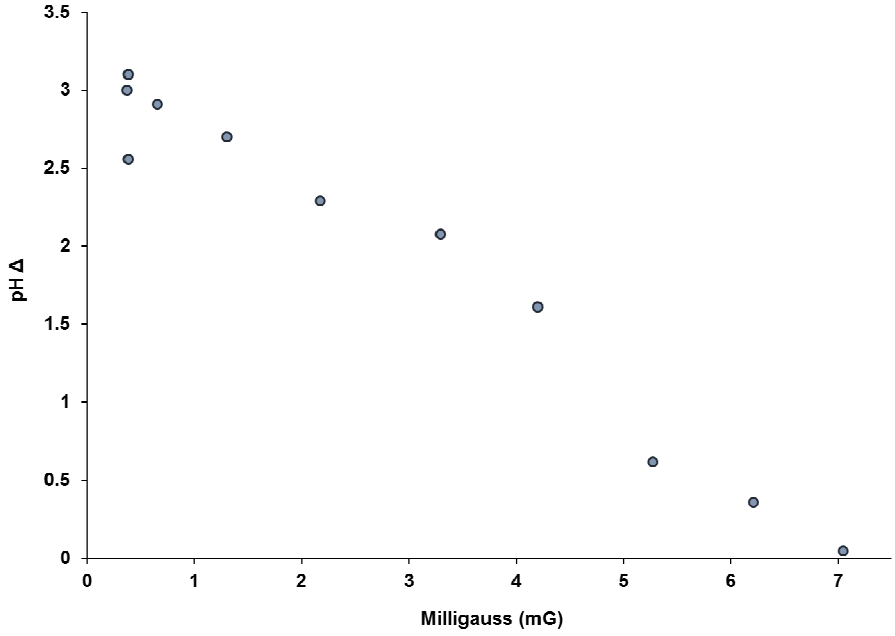

Fig. 5. Mean values for change (decrease) in pH as a function of magnetic field intensity to which the spring water was exposed following additions of a weak acid

4. DISCUSSION

The results of these experiments demonstrated that the intrinsic rates of the responses (shift to acidity) of a fixed volume of spring water to successive injections of a proton donor were delayed by a factor of approximately 5 when the water was exposed to a specific spatial and temporal configuration of weak circularly rotating magnetic fields. The maximum mean shift from 185 s to 885 s (~factor of 5) occurred within field intensities whose statistically significant discrepancies ranged by a factor of ~2.5 or

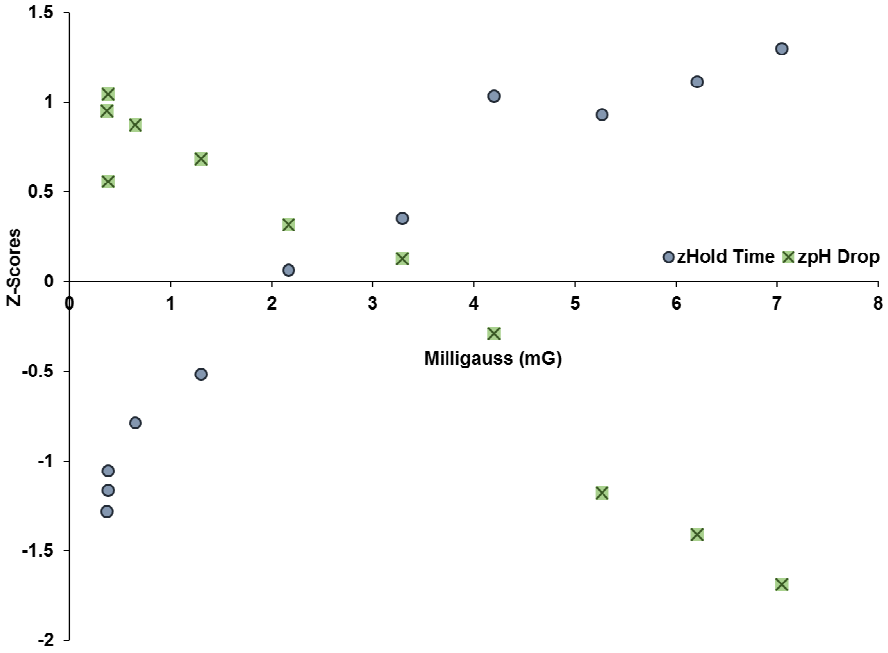

Fig. 6. Standardized scores for the increase in latency to display a shift towards acidity and the total decrease in pH as a function of field intensity (horizontal axis)

approximately 1.3 mG to 3.3 mG. The correlation coefficient between the mean values of the delay in shift in pH as a function of intensity was remarkably strong.

Because the cumulative consequence of the serial injections produced a net shift of ~3 pH units, from the beginning near-neutral values of the water (7.4) to 4.4, the results indicate that the presence of the magnetic field prevented the protons injected with each aliquot to contribute to the volume acidity for several hundreds of seconds compared to no field conditions. The strong inverse correlation between the duration of stability of pH and the net drop in pH when it occurred indicates the two processes were strongly interconnected.

The partial correlation analyses were completed to discern which phenomena, the protracted prevention of the shift in pH (the "holding effect") or the magnitude of the net increase in acidity were driving the reaction. Covarying for the other variable did not eliminate the correlation between the holding time and field intensity or the net decrease in pH and field intensity. This would suggest the field affected different processes that independently controlled the net change in pH and the holding effect.

If the sample size had been larger so that statistical significance had emerged, the smaller size of the partial correlations for the pH shift after the shared variance with holding time had been removed would be consistent with an interpretation that the duration of the protracted original pH (holding time) was the driving stimulus for the ultimate value of the net change in pH. This interpretation would congruent with a model where the magnetic field facilitated maintenance of the additional H^+ within some of the other solutes until some threshold was exceeded and the protons were released to contribute to the decreased pH.

The magnetic energy from the exposure of the 25 cc of water to the magnetic field can be estimated by:

$$E = (B^2 \cdot 2\mu^{-1})m^3 \quad (1)$$

where B is the field strength in Tesla, μ is magnetic permeability ($4\pi \cdot 10^{-7}$ $N \cdot A^{-2}$) and m^3 is volume. Within a 25 cc volume ($2.5 \cdot 10^{-5}$ m^3) of spring water the energy from a ~1 mG to 3.3 mG (10^{-7} T) magnetic field would be between $1 \cdot 10^{-13}$ J and $10.9 \cdot 10^{-13}$ J. In other words the increase of the energy available to maintain the processes responsible for the "holding time" would be about a factor of 10. If the intercept between the holding time and net change in pH is considered Fig. 6, the difference is a factor of 5 and well within the range of the increase in "holding" time

between the no field and maximum field conditions.

The quantitative evidence indicates that the most likely candidate of the many ions within the spring water that sequestered the additional protons would have been the HCO_3^- molecules. For 4 mM per L (the concentration within the spring water source containers) the numbers of ions within $2.5 \cdot 10^{-2}$ L (multiplied by Avogadro's number) would be $6.0 \cdot 10^{19}$ molecules. The numbers of H^+ (protons) within the original near-neutral solution (accommodating for the fact that 1 M of water is 18 cc), would have been $3.3 \cdot 10^{16}$. One experimental test of this hypothesis could involve different concentrations of bicarbonate and to discern the inflection points of the "dose-response" curve.

For the ultimate pH of 4.4, which was the final net shift of the solutions after various durations of magnetic field-dependent protraction of the original pH, the total numbers of H^+ would have been $2.4 \cdot 10^{19}$ which is within error range of the total concentration of bicarbonate ions. Thus when the cumulative concentration of H^+ approached the numbers of HCO_3^- ions the contributory effect of the magnetic energy from this particular configuration of changing angular velocity field was no longer maintained.

The energy from the most effective range for the intensity of the applied magnetic field per molecule would be $10.9 \cdot 10^{-13}$ J divided by $6.0 \cdot 10^{19}$ molecules or $1.8 \cdot 10^{-32}$ J per molecule. We think it is relevant that when this is divided by the average life time of each hydronium ion, about $\sim 10^{-12}$ s [3], the energy available per interaction for each H_3O^+ would be about $1.8 \cdot 10^{-20}$ J. This value is within the range of energy ($1.9 \cdot 10^{-20}$ J) associated with second shell hydrogen bonds and is consistent with measurements of the mobility of protons [3]. This quantity of energy is associated with a variety of important biological functions including the resting plasma membrane potential, the neuronal action potential, and the sequestering values for many ligand-receptor systems [12]. If thermal energies were interactive then slight changes in the average temperature of the water volume could significantly modify the duration of the "holding effect".

The contribution from the changing angular velocity of the circulating magnetic fields to the phenomena may be important from a general "quantum" perspective. The intrinsic frequency for the energies between $0.2 \cdot 10^{-32}$ J and $1.8 \cdot 10^{-32}$ J of magnetic energy per molecule in the band of intensities producing the "holding" effect is obtained by dividing by Planck's constant ($6.626 \cdot 10^{-34}$ J·s). The frequency is between 2.5 and 25 Hz. This would be within the range of the completion of one average rotation for the accelerating and decelerating velocities of the applied fields.

We applied the "physiologically-patterned" magnetic field rather than a classic sine wave because experimentally, for both living and "non-living" systems that involve water, the latter is not as effective at low intensities in the order of 1 μT. Our samples of water were not disturbed (mechanically). Consequently, the applied fields may have interacted with emerging thixotropic effects [13] and the associated increased viscous properties. As aptly stated by Verdel and Bukovec [13] the stretching and distortion excitations of OH of water molecules decay within the femtosecond range while the lifetime of hydrogen bonds is in the order of 1 ps or approximately that of the life time of H_3O^+. The emergence of long-range forces extending from gel surfaces, such as water adjacent to a surface, is known to be associated with forming structured concentrations of protons at the interface with bulk water [14,15]. All of these conditions could produce the condition for applied magnetic fields with congruent configurations to be embedded within a maintained organized field of protons.

5. CONCLUSION

Appropriately, temporally patterned, rotating magnetic fields that exhibit specific rates of change for angular velocities maintained the baseline, near-neutral pH of a quantity of spring water even after repeated microinjections of H^+ donors. Quantitative estimates support the conclusion that this "holding" effect during exposure to these particular "weak" magnetic fields was determined by the intensity-dependent energy added to the intrinsic sequestering of H^+ within clusters of ions within the spring water. The phenomenon may offer an alternative explanation for anomalous buffering systems.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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